Does inclusive pion double charge exchange (DCX) drop rapidly above 0.5 GeV?

A.Krutenkova (ITEP, Moscow, Russia) for KEK(SKS)-ITEP collaboration

CONTENTS

- Introduction (exclusive and inclusive pion DCX)
- Forward inclusive pion DCX above 0.5 GeV
- KEK T459 experiment with SKS: $^{16}O(p^-,p^+)X$
- Study of positron background
- Outgoing pion energy spectra at 0.5 and 0.75 GeV
- Energy dependence of forward inclusive pion DCX
- Conclusion and outlook

Introduction

Pion double charge exchange on nucleus (DCX)

exclusive DCX: p$^-$ + A(Z,N) ® p$^+$ +A'(Z - 2,N + 2),
p$^+$ + A(Z,N) ® p$^-$ +A'(Z + 2,N - 2)
inclusive DCX: p$^{-/+}$ + A(Z,N) ® p$^{+/-}$ + **X**

- Two like nucleons (protons or neutrons) are needed
- Tool to study short-range two nucleon correlations
  [A.DeShalit, S.D.Drell, H.Lipkin (1961); T.Ericson, 1963]

Conventional mechanism of pion DCX

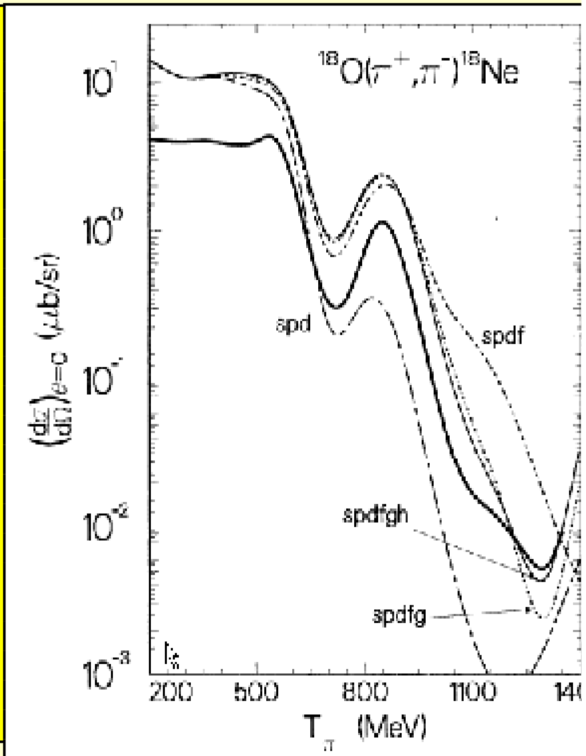
Two sequential single charge exchanges with real π^0
in intermediate state (SSCX mechanism):

- reasonably describes energy behavior of forward DCX
  at incident energies T_π º T_0 = 0.3-0.5 GeV
- predicts rapid drop (with two dips)
  of pion DCX cross section at T_0 = 0.5-1.3 GeV
  due to decrease of single charge exchange πN amplitude

[This effect is valid for exclusive and for inclusive DCX]

Unique testing ground for unconventional mechanisms

[D.Strottman (1988), E.Oset, and D.Strottman (1989),
M.Arima, and R.Seki (1989)]



ds/dW (mb/sr) at q = 0^o

Glauber-type model
[modern pN phase shifts,
partial waves up to l = 5,
effects of absorptions, spin flips
and nuclear core polarization
(renormalizations of pN amplitude)]
No free parameters

[E.Oset, and D.Strottman (1993)]

Forward inclusive pion DCX above 0.5 GeV

- Experimental observation [ITEP, B.M.Abramov et al, 1996, 2003]

ITEP experiment (inclusive pion DCX on ^{6}Li, ^{7}Li, ^{12}C and ^{16}O)

10-GeV PS, pion beam ~10^{5} pions/spill, 3m magnet spectrometer with spark chambers, and large Čerenkov counter to distinguish positrons from outgoing pions

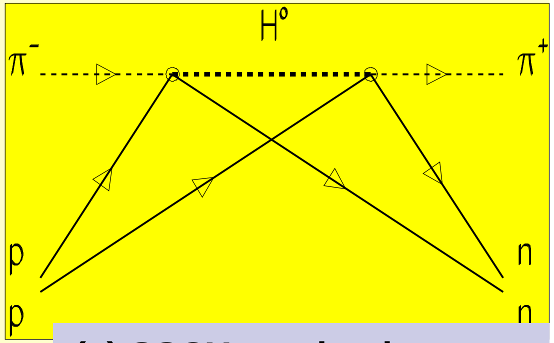
Incident energies: T_0 = 0.6, 0.75 and 1.1 GeV; q =0-10^{0}

Kinematical region: DT = T_0 - T < 140 MeV (T is outgoing pion energy) where additional p production is forbidden by energy-momentum conservation

DT scale calibration: p^{-} + p ® p + p^{-}; s (DT) = 6-8 MeV

Result: Effect of rapid drop of forward inclusive pion DCX rate is absent: relatively slow decrease of DCX cross section at 0.6-1.1 GeV

Conclusion: New mechanism, other than SSCX does contribute to forward inclusive pion DCX



(a) SSCX mechanism:
H^0 = p^0 (elastic)
(b) Glauber inelastic rescatterings (IR):
H^0 = p^-p^+, p^0p^0

- Theoretical interpretation (new DCX mechanism) [A.B.Kaidalov, and A.P.Krutenkova, 1997, 2001]

In framework of *Gribov* relativistic QFT approach: *Glauber* inelastic rescatterings (IR) with multipion intermediate state contribute at higher energies

OPE model calculations: IR with H^0 = p^-p^+, p^0p^0 dominate over SSCX (H^0 = p^0) at T_0 ³ 0.6 GeV

Existing p beams to check ITEP observation: KEK, BNL, GSI

PHYSICAL REVIEW C **72**, 037602 (2005); nucl-ex/0502017

Inclusive pion double charge exchange on ^{16}O above the Δ resonance

A.P.Krutenkova[1], T. Watanabe[2], D. Abe[2], Y.Fujii[2], O. Hashimoto[2], V.V. Kulikov[1], T. Nagae[3], M. Nakamura[4], H. Noumi[3], H. Outa[3], P.K. Saha[5], T.Takahashi[2], H.Tamura[2]

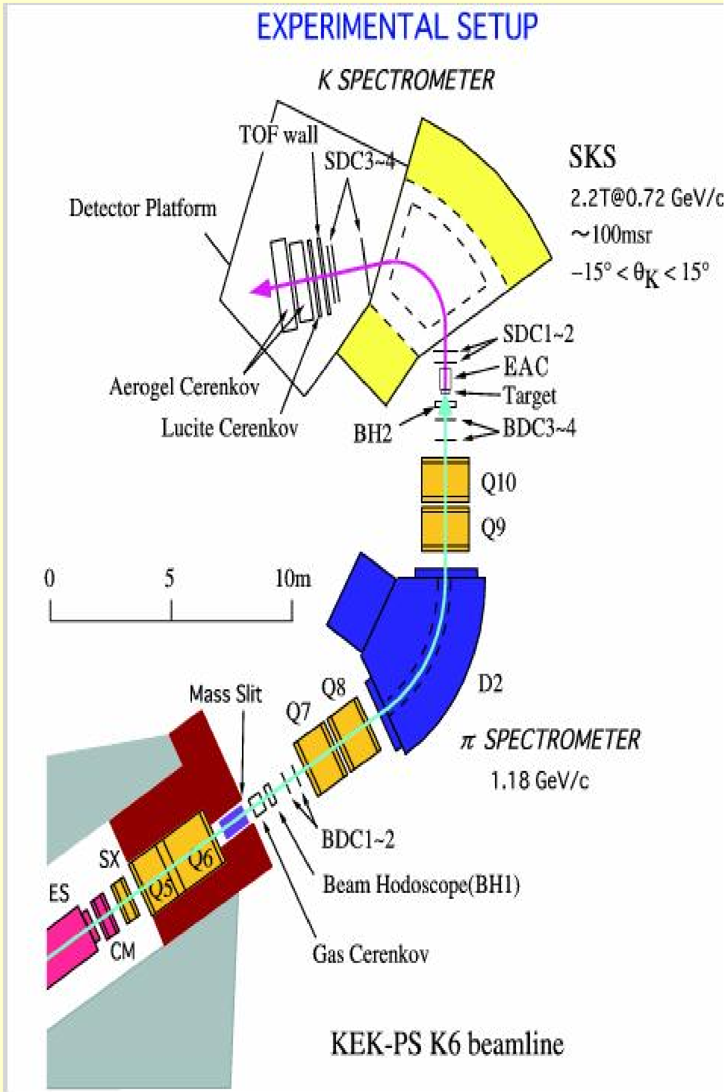
[1] Institute of Theoretical and Experimental Physics, Moscow, Russia
[2] Department of Physics, Tohoku University, Sendai, Japan
[3] High Energy Accelerator Research Organization (KEK), Tsukuba, Japan
[4] Graduate School of Science, University of Tokyo, Japan
[5] Japan Atomic Energy Research Institute, Tokai, Japan

KEK T459 experiment: π^- + ^{16}O ® π^+ + X

- 12 GeV PS KEK, K6 beam (1-2)·10^6 pions/spill
- Apparatus of π^- ® K^+ (E438) experiment: superconducting kaon spectrometer (SKS) with drift chambers (without Aerogel Čerenkovs)
- DT scale calibration: π^- + p ® K^+ + S^-
  s(DT) = 2-3 MeV
  [H.Noumi et al. (2002), P.K.Saha et al. (2004)]
- Incident energies:
  T_0 = 0.50 GeV (I_{sks}=145 and 175A)
  T_0 = 0.75 GeV (I_{sks}= 272 and 320A)
- Outgoing pion angle: $\theta < 15^o$
- 5-cm long H_2O target

Kinematical region: 0 < DT < 140 (or 80) MeV

Trigger BH1 x BH2 x $\overline{\text{GC}}$ x TOF x LC:
(e^- + π^-) + A ® (e^+ + π^+ + p) + X
Beam e^- suppression : GC
Proton background suppression: LC, TOF
Positron background study: special run with EAC



Positron background

Sources of positrons

- beam electrons: e^- ® g ® e^+ in target
- single charge exchange of beam pions: π^- ® π^0 ® e^+

Special run to study e^+ background

- additional aerogel (n=1.01) Čerenkov EAC behind target
- $e^\pm$ and $\pi^\pm$ identification with GC and EAC

Trigger BH1´BH2 without target
[(e^- + π^-) beam through]

- choice of thresholds and measurement of efficiencies e_{GC} and e_{EAC} to pions and electrons/positrons

Trigger BH1´BH2´TOF´LC ((e^- + π^-) ® (e^+ + π^+))

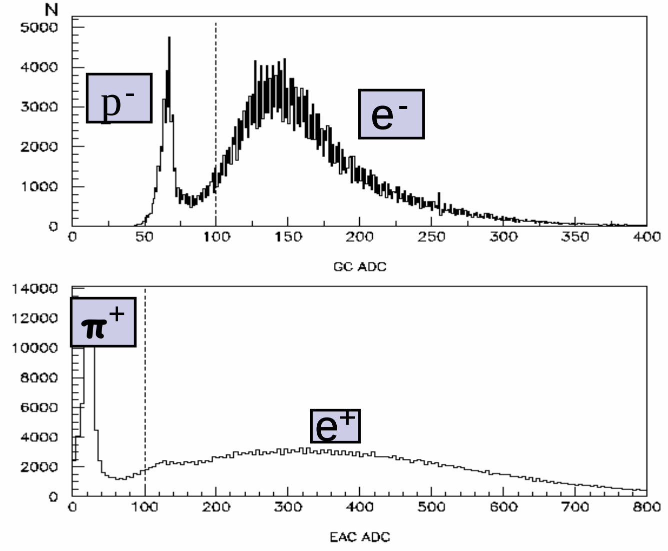
- detection of "raw" reactions (π^-,π^+), (π^-,e^+), (e^-,π^+), (e^-,e^+)
- choice of angular interval of 4°<q<6° away from sharp (e^-,e^+) peak at 0°

Correction factor B obtained from raw data for interval 0 < DT < 140 MeV using e_{GC} and e_{EAC}:

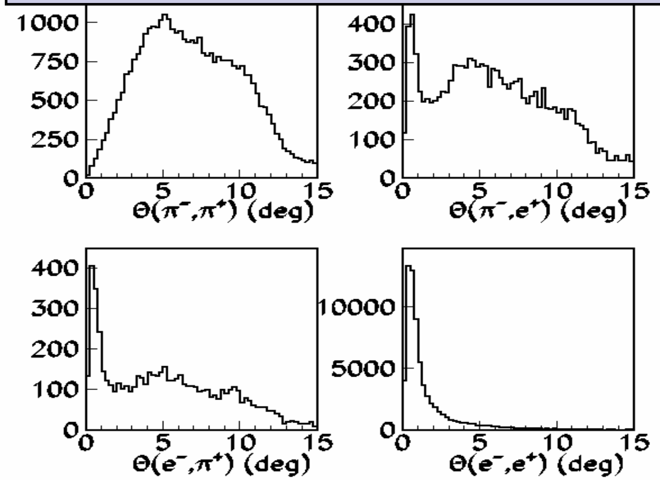
B = $N(e^+)/[N(e^+) + N(\pi^+)]$ =
= 0.54 ± 0.08 (0.35 ± 0.06) for T_0 = 0.50 (0.75) GeV

[B(DT) » B within experimental errors]

Choice of Čerenkov thresholds



Raw angular distributions at T_0 = 0.75 GeV. Efficiencies e_{GC}=0.94(0.095), e_{EAC}=0.87(0.13) for electrons (pions)



π^+ energy spectra in reaction π^- + ^{16}O ® π^+ + X

Event selection of π^- + ^{16}O ® (e^+,π^+) + X:
standard SKS procedure, and 4° < q < 6° cut

DT upper cut (MeV):
DT<80 DT<140

T_0, GeV	I_{SKS}, A	N_{p^-} X10^9	N_{tot}	N_{80}	N_{140}
0.5	145	7.2	1599	197	1033
0.5	175	15.7	1017	433	-
0.75	272	25.2	7710	362	1661
0.75	320	32.6	4859	621	2449

Cross section evaluation for π^{-16}O ® π^+X:

$(d^2s/dWdT)=(A/rN_{Av})(DWDT)^{-1}\cdot N(1-B)/N_{\pi^-}\, f$

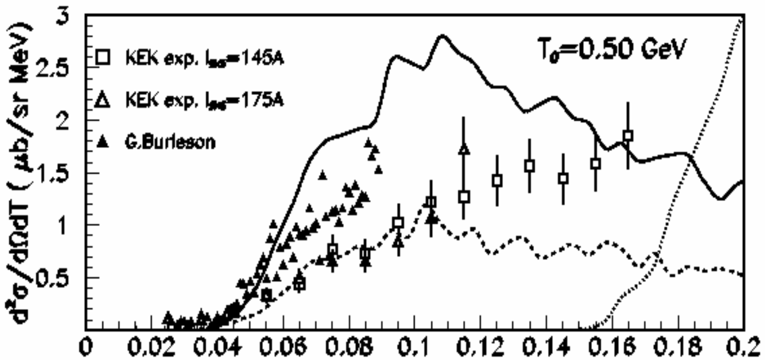
$f = \prod f_i$ = 0.320±0.005 and 0.304±0.004
for T_0 = 0.5 GeV and 0.75 GeV
(f_i are corrections for m contamination, efficiencies of detectors and analysis, and p decays)

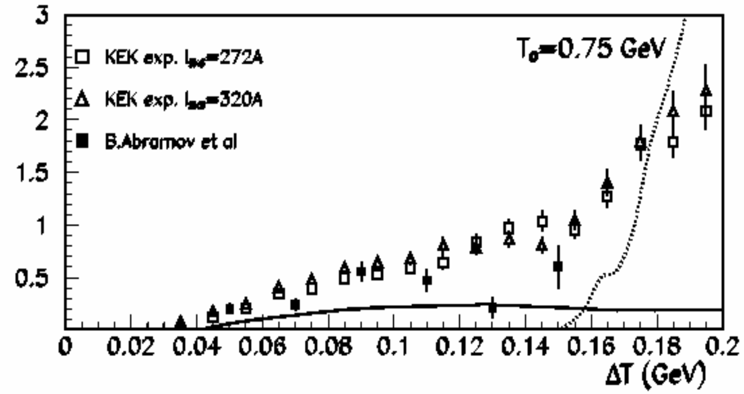
Results for different I_{SKS} agree,
$d^2s/dWdT$ increases with DT

For T = 0.75 GeV π^{-16}O ® π^+ π^- X contributes

Experiments: KEK, LAMPF, ITEP

Cascade type calculations:
SSCX mechanism (solid curve),
SSCX + core polarization (dashed curve),
π^{-16}O ® π^+ π^- X (dotted curve)
[M.J.Vicente Vacas, L.Alvarez-Ruso (2003)]





Integrated forward inclusive DCX cross section

$$\langle d\sigma/d\Omega\rangle_{140(80)} = \int_0^{140(80)} (d^2\sigma/d\Omega dT)\, d\Delta T$$

	$\langle d\sigma/d\Omega\rangle_{80}$		$\langle d\sigma/d\Omega\rangle_{140}$	
T_0,GeV	0.50	0.75	0.50	0.75
μb/sr	15.9±3.2	14.1±1.5	96.2±17.5	56.1±5.4

Statistical error: due to $N_{140(80)}$, ΔB
Systematic error: 10% (ΔT scale mainly)

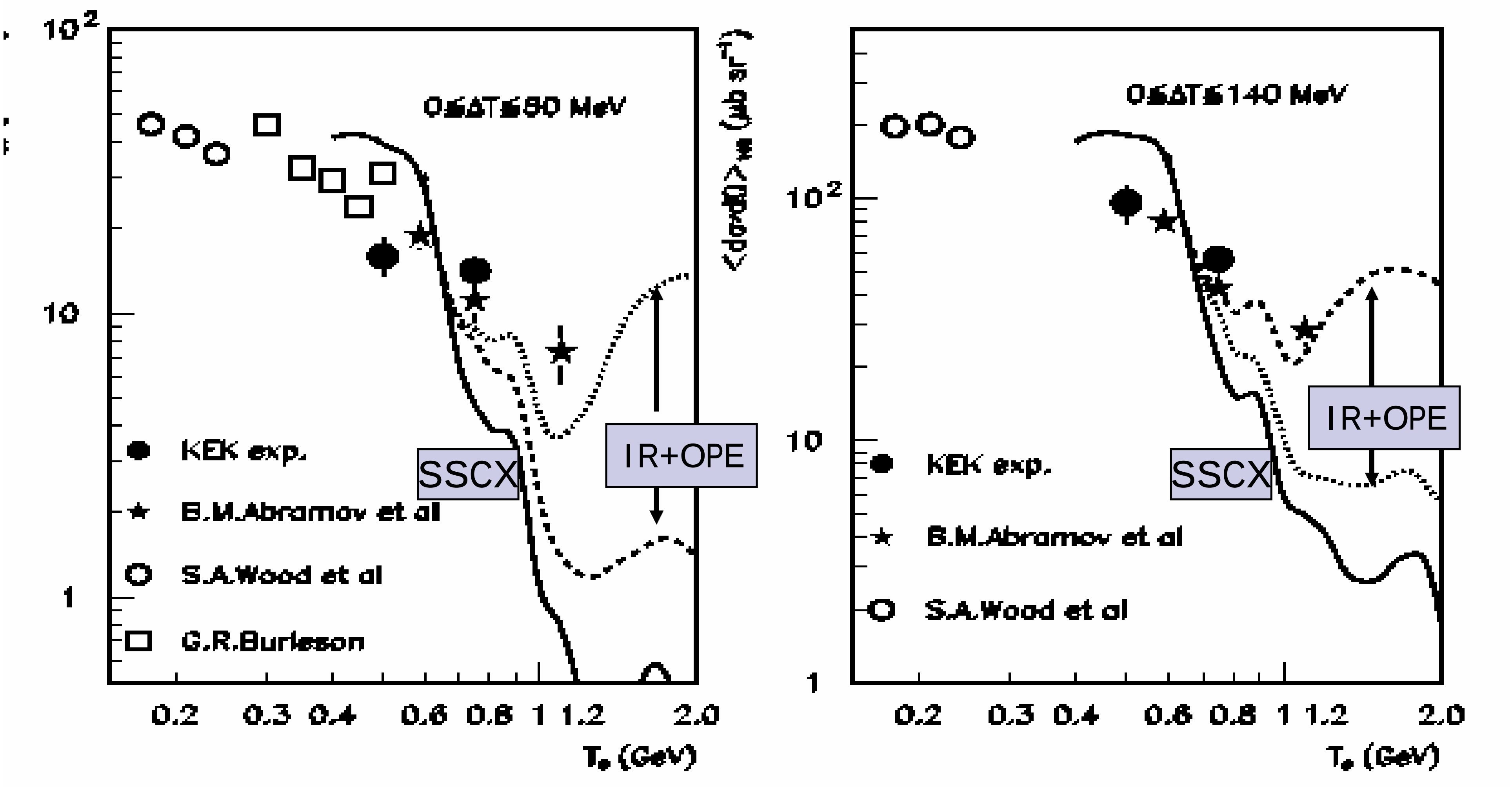
$$\frac{\langle d\sigma/d\Omega\ (0.5)\rangle_{140}}{\langle d\sigma/d\Omega\ (0.75)\rangle_{140}} = 1.7 \pm 0.2$$

(SSCX mechanism predicts 7.2 !)

SSCX *vs* data: large discrepancy

T_0 dependence of forward inclusive DCX cross section

$\pi^- + {}^{16}O$ ® $\pi^+ + X$



[IR + OPE: A.B.Kaidalov, and A.P.Krutenkova, 2001]

Conclusion

- Cross section of forward inclusive DCX reaction $\pi^- + {}^{16}O \rightarrow \pi^+ + X$ was measured at SKS (KEK) for $T_0 = 0.5$ and 0.75 GeV

- $\mathbf{R} \equiv \langle d\sigma/d\Omega\,(0.5\ \mathrm{GeV})\rangle_{140} / \langle d\sigma/d\Omega\,(0.75\ \mathrm{GeV})\rangle_{140} = 1.7 \pm 0.2$ is significantly less than $\mathbf{R} \approx 7$ predicted by SSCX

  Inclusive σ(DCX) does NOT drop rapidly at $T_0 > 0.5$ GeV which supports ITEP results

- At $T_0 > 0.5$ GeV SSCX mechanism with real π^0 (elastic Glauber rescattering) does not dominate

- New mechanism (inelastic Glauber rescatterings) with two pions in the intermediate state seems to be a good candidate

Outlook

•

- Measurements of inclusive DCX up to 2.5 GeV are needed to support conclusion on relatively slow σ(DCX) decrease and to study inelastic rescatterings

Earlier, the related ITEP proposal was approved by GSI Committee

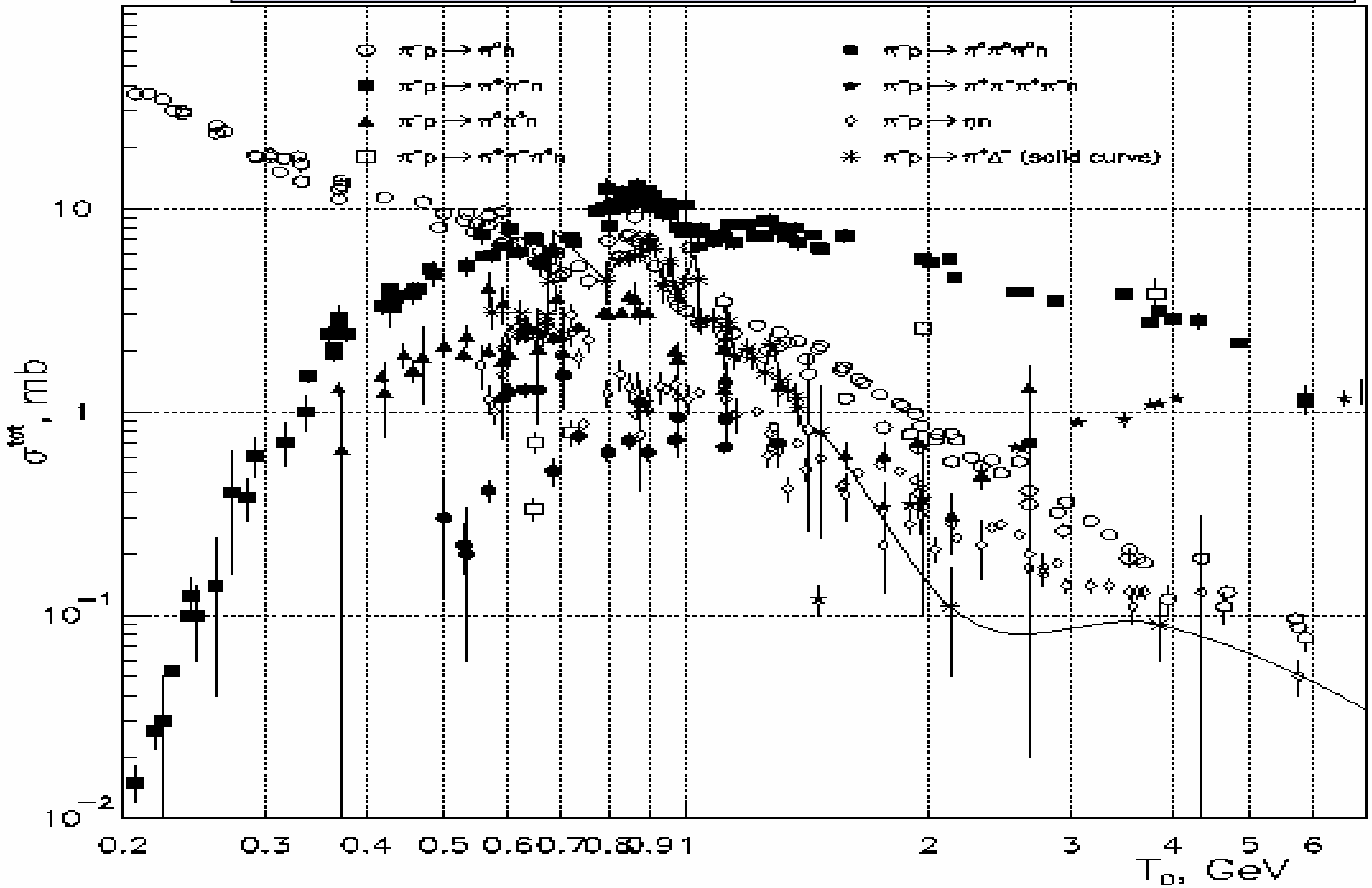
However dedicated set-up was not found so far

- Comparative measurements of exclusive and inclusive σ(DCX) in the same experiment are desirable

Proposal to use SKS at JPARC for such studies is planned

Problems: ^{18}O or ^{14}C target, wide-aperture Čerenkov

Experimental data from V.Flaminio (compilation), 1983



Experimental total cross sections for reactions
p^- + p ® H + n (H is meson state) and p^- + p ® π^+ + D